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[54] **PIEZO ACTIVATED PUMP IN AN INK LIQUID SUPPLY SYSTEM**

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[30] **Foreign Application Priority Data**

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[51] **Int. Cl.**[4] **G01D 15/18**

[52] **U.S. Cl.** .... **346/140 R**; 310/369; 346/75; 417/322

[58] **Field of Search** 346/75, 140; 417/322, 417/394, 389, 478; 310/369, 346

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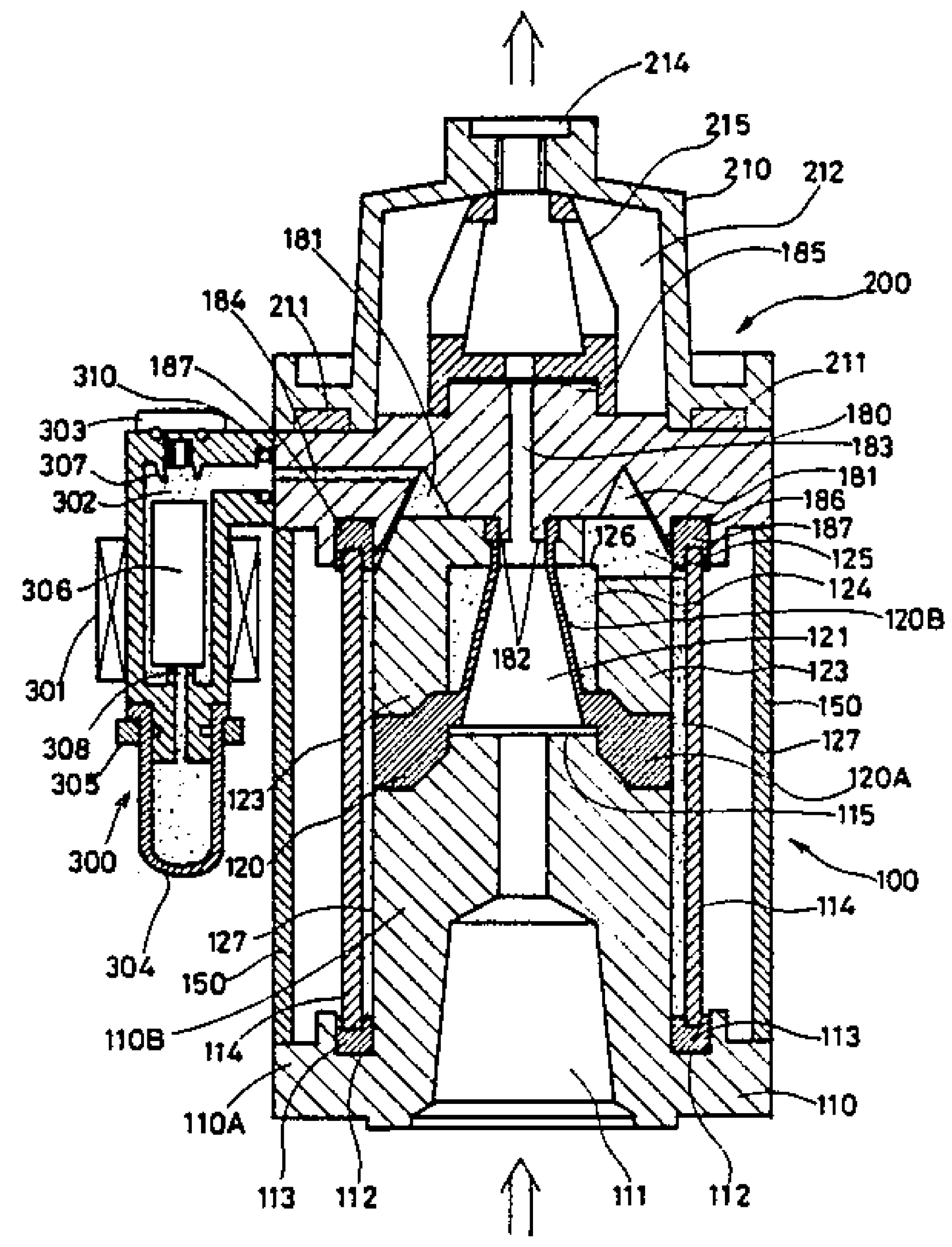
Primary Examiner—Joseph W. Hartary
Attorney, Agent, or Firm—Birch, Stewart, Kolasch & Birch

[57] **ABSTRACT**

A piezo activated liquid supply pump system includes a cylinder shaped vibration pipe made of a piezo element, and a cone shaped pressure chamber surrounded by a rubber wall. The cone shaped pressure chamber is disposed in the cylinder shaped vibration pipe in a manner that a cavity is formed therebetween. Polyethylene glycol is filled in the cavity for transferring the vibration of the piezo element to the rubber wall of the cone shaped pressure chamber. The volume of the pressure chamber varies in response to the vibration of the piezo element to achieve the liquid supply. The cone configuration of the pressure chamber ensures an effective removal of air bubbles from the pressure chamber. The cavity is communicated with a buffer chamber so as to introduce the polyethylene glycol into the buffer chamber when the liquid contained in the pressure chamber freezes, whereby the expansion of the pressure chamber caused by the freezing of the liquid is absorbed.

4 Claims, 4 Drawing Figures



PRIOR ART

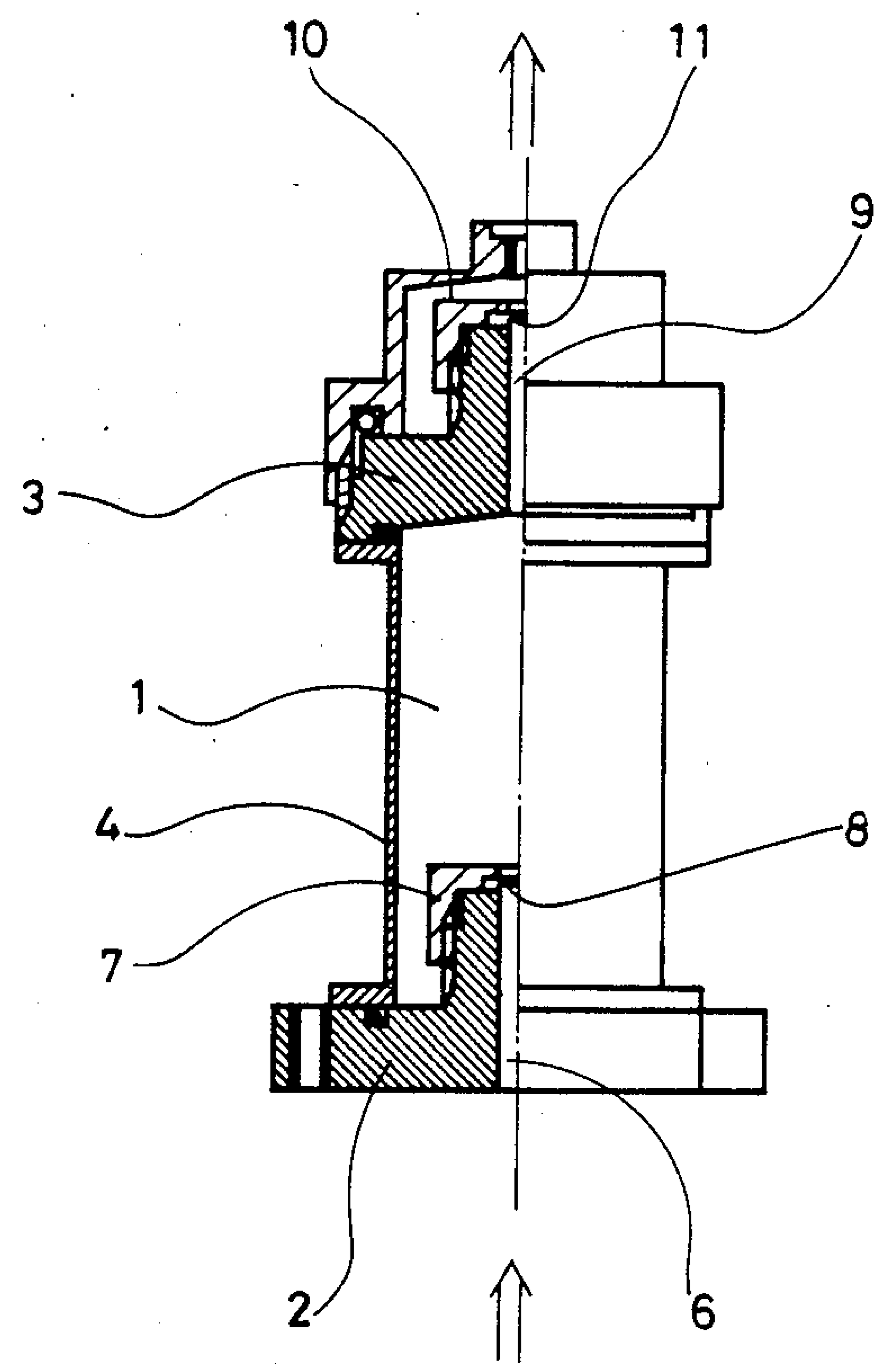


FIG.1

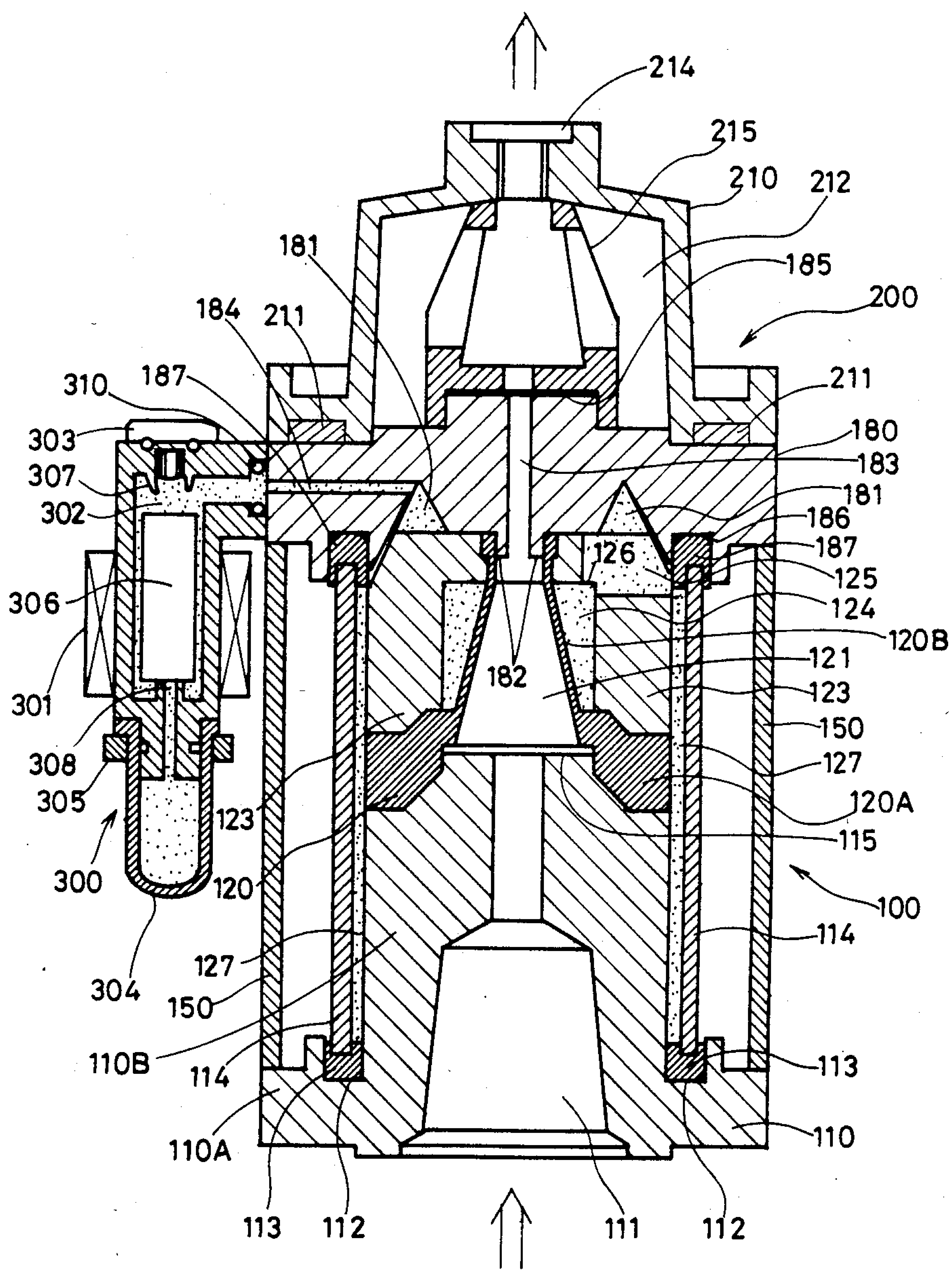

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FIG. 2

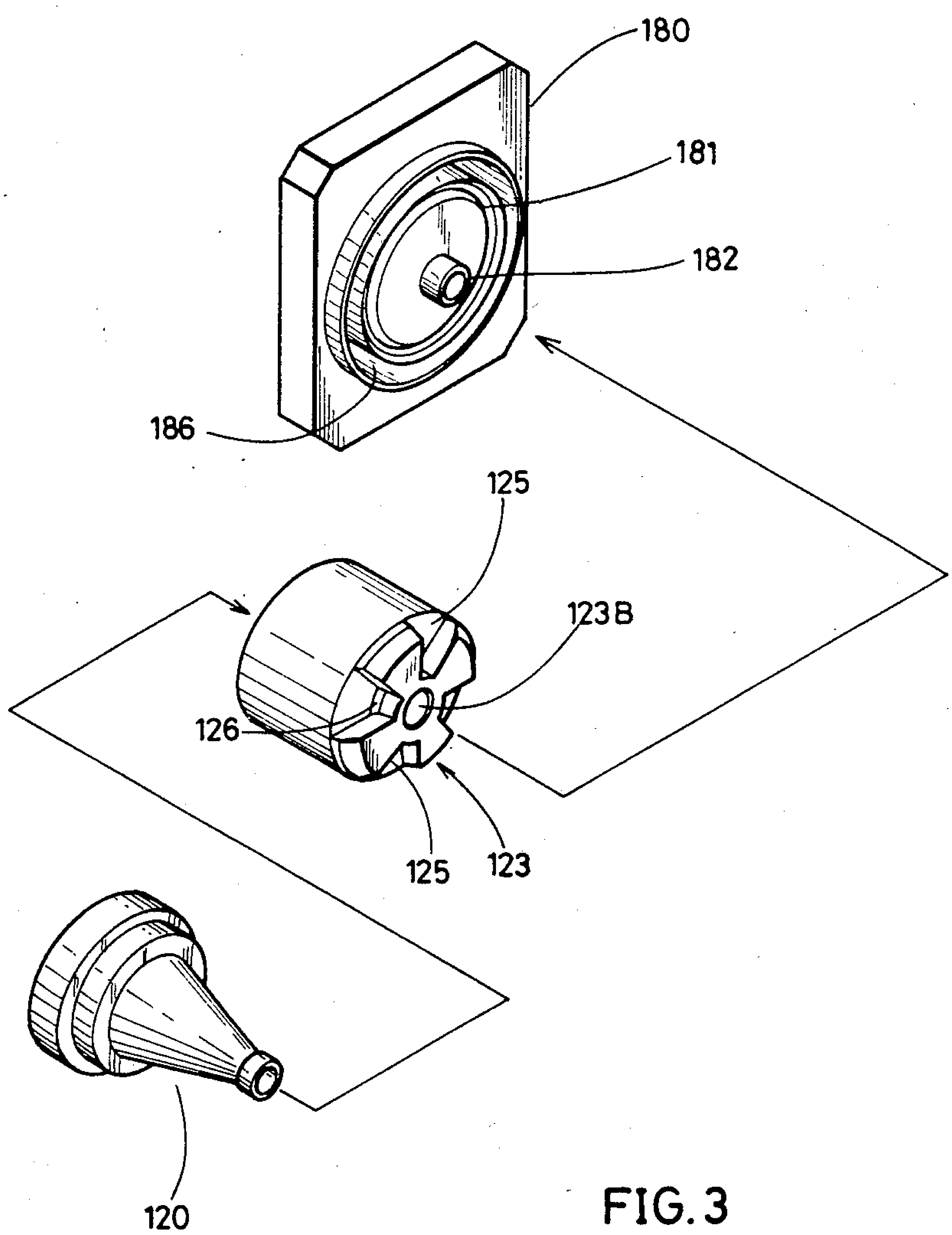

FIG. 3

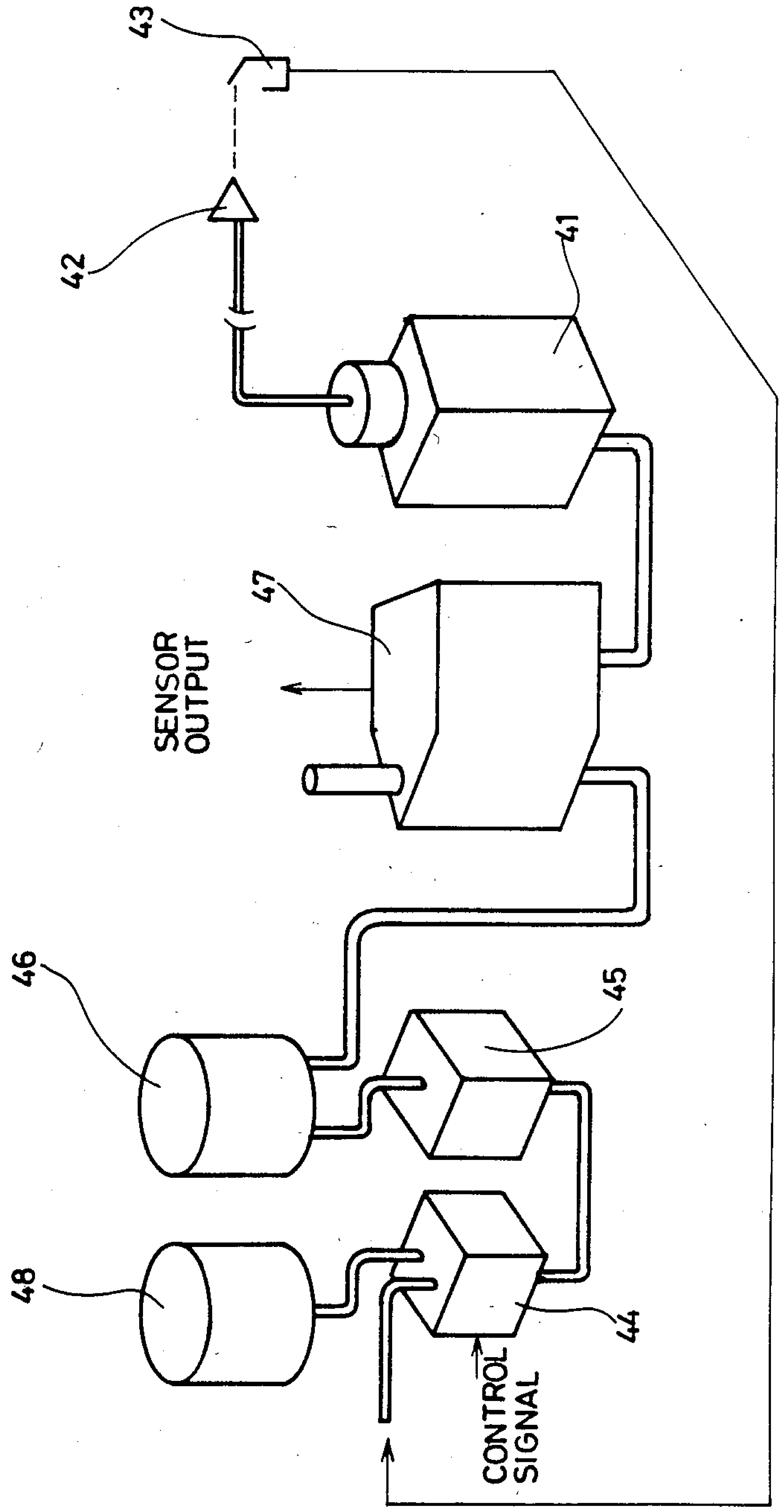

FIG.4

PIEZO ACTIVATED PUMP IN AN INK LIQUID SUPPLY SYSTEM

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

The present invention relates to a pump system in a liquid supply system and, more particularly, to a piezo activated pump system in an ink liquid supply system for an ink jet system printer of the charge amplitude controlling type.

2. DESCRIPTION OF THE PRIOR ART

An ink jet system printer of the charge amplitude controlling type requires a small amount, constant flow rate pump system in order to ensure stable printing operation even when the ambient condition varies.

The conventional ink liquid supply system in an ink jet system printer of the charge amplitude controlling type employs a mechanical plunger pump of the constant flow rate type. However, the mechanical plunger pump does not ensure stable constant flow rate supply when the supply amount is very little. Furthermore, the mechanical plunger pump occupies a considerably large size.

To ensure stable constant flow rate supply even when the supply amount is very little, a piezo activated pump system has been proposed, wherein an piezo element is employed to vary the size of a pump chamber. An example of the piezo activated pump system is described in copending U.S. Patent Application, "INK LIQUID SUPPLY SYSTEM IN AN INK JET SYSTEM PRINTER OF THE CHARGE AMPLITUDE CONTROLLING TYPE", Ser. No. 510,355, filed on July 1, 1983 by Masaaki KURANISHI, Masahiko AIBA, Hideyuki MIYAKE and Naohiro OKU, and assigned to the same assignee as the present application. The Japanese counterpart is Japanese Patent Application No. 57-118240 filed on July 6, 1982; the British counterpart was filed on July 1, 1983 and assigned application No. 8317915; the German counterpart was filed on July 6, 1983 as P 33 24 397.2; and the Canadian counterpart was filed on July 5, 1983 and assigned Ser. No. 431,844.

In the piezo activated pump system describe in the abovementioned copending application, the pressure chamber is defined by a cylinder shaped piezo element. Therefore, the pressure chamber configuration is fixed to the cylinder shape. The cylinder configuration precludes effective removal of air bubbles from the pressure chamber when the air bubbles are included in the ink liquid supplied to the piezo activated pump system.

Furthermore, the pressure chamber surrounded by the piezo element mey explode when the ink liquid contained in the pressure chamber freezes. This is because the thin piezo element can not endure the expansion of the ink liquid when the ink liquid freezes. The freezing of the ink liquid will take place when the ink jet system printer is placed in a non-operating condition or when the ink jet system printer is transported from one office to another one in a low temperature atmosphere.

OBJECTS AND SUMMARY OF THE INVENTION

Accordingly, an object of the present invention is to provide a novel piezo activated pump system suited for an ink liquid supply system to an ink jet system printer of the charge amplitude controlling type.

Another object of the present invention is to provide a piezo activated pump system which ensures effective bubble removal from the pressure chamber.

Still another object of the present invention is to protect the piezo activated pump system from explosion when the ink liquid contained in the pressure chamber freezes.

Other objects and further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. It should be understood, however, that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

To achieve the above objects, pursuant to an embodiment of the present invention, a cylinder shaped vibration pipe is formed by a piezo element. A cone shaped pressure chamber formed by rubber is disposed in the cylinder shaped vibration pipe. Liquid such as a polyethylene glycol is disposed between the cylinder shaped vibration pipe and the cone shaped pressure chamber to transfer the vibration of the piezo element to the pressure chamber. The cone configuration of the pressure chamber facilitates the removal of bubbles from the ink liquid disposed in the pressure chamber.

In a preferred form, a buffer chamber is provided, which is selectively communicated with the liquid disposed between the cylinder shaped vibration pipe and the cone shaped pressure chamber via a valve. When the ink jet system printer is placed in a non-operating condition for a long period, the valve is opened to allow the liquid to flow toward the buffer chamber. Under these conditions when the ink liquid disposed in the pressure chamber freezes, the pressure chamber expands. The expansion of the pressure chamber is absorbed by the buffer chamber because the liquid disposed between the vibration pipe and the pressure chamber flows into the buffer chamber, thereby protecting the piezo activated pump from explosion even when the ink liquid disposed in the pressure chamber freezes.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be better understood from the detailed description given hereinbelow and the accompanying drawings which are given by way of illustration only, and thus are not limitative of the present invention and wherein:

FIG. **1** is a partially sectional front view of a piezo activated pump system of the prior art;

FIG. **2** is a sectional view of an embodiment of a piezo activated pump system of the present invention;

FIG. **3** is an exploded perspective view of an essential part of the piezo activated pump system of FIG. **2**; and

FIG. **4** is a schematic block diagram of an ink liquid supply system for an ink jet system printer of the charge amplitude controlling type, including the piezo activated pump system of FIG. **2**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. **1** shows a conventional piezo activated pump system which is described in copending U.S. Patent Application Ser. No. 510,355.

The conventional piezo activated pump system includes a pressure chamber **1** which introduces and develops ink liquid in the direction shown by arrows. The pressure chamber **1** includes a side wall formed by a cylinder shaped vibration pipe **4** made of a piezo element. A valve seat **2** is secured to one end of the cylinder shaped vibration pipe **4**, and another valve seat **3** is secured to the other end of the cylinder shaped vibration pipe **4**. An inlet valve **8** is secured to the valve seat **2** by means of a valve guard **7** to selectively connect the pressure chamber **1** to an inlet passage **6**. An outlet valve **11** is secured to the valve seat **3** by means of a valve guard **10** so as to selectively connect the pressure chamber **1** with an outlet port via an outlet passage **9**.

The cylinder shaped vibration pipe **4** has a thickness of about 0.2 mm. When a pulse signal is applied to the cylinder shaped vibration pipe **4**, the volume of the pressure chamber **1** varies to supply the ink liquid in the direction shown by the arrows. The piezo activated pump system ensures a constant flow rate supply in a small amount supply.

The vibration pipe **4** must be the cylinder shape in order to ensure an effective vibration of the piezo element. Thus, the pressure chamber **1** of the conventional system must be the cylinder shape. The cylinder configuration precludes an effective removal of air bubbles from the pressure chamber **1** when the air bubbles are contained in the ink liquid introduced into the pressure chamber **1**. Furthermore, when the ink liquid filled in the pressure chamber **1** freezes while the ink jet system printer is placed in a non-operating condition, there is a possibility that the piezo activated pump system explodes due to the expansion of the ink liquid because the vibration pipe **4** is considerably thin.

FIGS. **2** and **3** show an embodiment of a piezo activated pump system of the present invention, which includes a pressurizing pump unit **100**, a ripple regulating unit **200**, and a buffer unit **300**. The pressurizing pump unit **100** includes an inlet valve seat **110**, an outlet valve seat **180**, and a cylinder shaped frame **150** disposed between the inlet valve seat **110** and the outlet valve seat **180**. The ripple regulating unit **200** includes a frame **210** which is secured to the outlet valve seat **180** through the use of screws. The buffer unit **300** is secured to the side of the outlet valve seat **180** through the use of screws.

The inlet valve seat **110** is provided with an inlet passage **111** formed through the center of the valve seat **110**. The inlet passage **111** is connected to an ink liquid reservoir (not shown) in order to introduce the ink liquid into the piezo activated pump system. A circular shaped groove **112** is formed at a flange portion **110A** of the inlet valve seat **110**. A rubber seal **113** is disposed in the circular shaped groove **112**.

A cylinder shaped vibration pipe **114** made of a piezo element is disposed on the circular shaped groove **112** with the intervention of the rubber seal **113**. A cavity **127** is formed between the cylinder shaped vibration pipe **114** and a body portion **110B** of the inlet valve seat **110**. A plate shaped check valve **115** is disposed on the body portion **110B** of the inlet valve seat **110** so as to cover the inlet passage **111**. A cone shaped separator rubber **120** is secured to the body portion **110B** of the inlet valve seat **110** in order to define a pressure chamber **121** which is communicated with the inlet passage **111** through the plate shaped check valve **115**.

The cone shaped separator rubber **120** is preferably made of EPDM rubber, for example, "D1418" expressed by the ASTM standard. The cone shaped separator rubber **120** integrally includes a base portion **120A** which has the same diameter as the body portion **110B** of the inlet valve seat **110**, and a cone portion **120B** which has a thin wall to define the cone shaped pressure chamber **121**. The cone configuration of the pressure chamber **121** ensures an effective bubble removal from the pressure chamber **121** when air bubbles are included in the ink liquid supplied from the inlet passage **111** of the pressure chamber **121**. The cone shaped separator rubber **120** vibrates in response to the vibration of the cylinder shaped vibration pipe **114**, thereby varying the volume of the pressure chamber **121**.

A separator cap **123** made of resin is disposed on the base portion **120A** of the cone shaped separator rubber **120** in a manner to surround the cone portion **120B** of the cone shaped separator rubber **120**. The separator cap **123** includes a hole **123B**, as shown in FIG. **3**, in which the tip end of the cone portion **120B** of the cone shaped separator rubber **120** is engaged. A hollow portion **124** is formed between the outer surface of the cone shaped separator rubber **120** and the inner surface of the separator cap **123**. Four cutaway portions **125** are formed on the upper surface of the separator cap **123**. Passages **126** are formed at the cutaway portions **125** in order to communicate the cutaway portion **125** with the hollow portion **124**. The outlet valve seat **180** is disposed on the separator cap **123**.

The outlet valve seat **180** is provided with a circular shaped groove **186** at the position confronting the circular shaped groove **112** formed in the inlet valve seat **110**. A rubber seal **187** is disposed in the circular shaped groove **186**. The upper end of the cylinder shaped vibration pipe **114** is supported by the circular shaped groove **186** with the intervention of the rubber seal **187**. The above-mentioned cavity **127** is continuously formed around the body portion **110B** of the inlet valve seat **110**, the base portion **120A** of the cone shaped separator rubber **120**, and the separator cap **123**.

Another circular shaped groove **181** of a shorter diameter is formed in the outlet valve seat **180**. An outlet passage **183** is formed through the center of the outlet valve seat **180**. A protruded portion **182** is formed on the bottom surface of the outlet valve seat **180** at the position where the outlet passage **183** is formed, the protruded portion **182** being inserted into the hole **123B** of the separator cap **123** and connected to the upper end of the cone shaped separator rubber **120**. The circular shaped groove **181** is communicated with the cutaway portions **125** of the separator cap **123** so that the circular shaped groove **181** is communicated with the cavity **127** and the hollow portion **124**. The circular shaped groove **181** is connected to a passage **184** formed in the outlet valve seat **180**. The buffer unit **300** communicates with the passage **184**. A plate shaped check valve **185** is disposed on the outlet valve seat **180** to cover the outlet passage **183**. The cylinder shaped frame **150** is disposed between the inlet valve seat **110** and the outlet valve seat **180** to surround the cylinder shaped vibration pipe **114** with a clearance therebetween.

The thus constructed pressurizing pump unit **100** introduces the ink liquid from the inlet passage **111** into the cone shaped pressure chamber **121** defined by the cone shaped separator rubber **120** and the outlet passage **183**. The volume of the cone shaped pressure chamber **121** varies by the deformation of the cone portion **120B** of the cone shaped separator rubber **120**, whereby the ink liquid is developed from the cone shaped pressure chamber **121** through the plate shaped check valve **185**.

A liquid having a low freezing point, such as polyethylene glycol, is filled in the circular shaped groove **181**, the cutaway portions **125**, the hollow portion **124** and the cavity **127**.

The frame **210** of the ripple regulating unit **200** is secured to the outlet valve seat **180** via a rubber seal **211** to form a chamber **212** therein. At the upper end of the frame **210**, an outlet **214** is formed which is connected to a nozzle unit of an ink jet system printer. The frame **210** is made of a resilient member, for example, polyacetal resin. The resilience functions to regulate the ripples included in the pressurized ink liquid. A valve guard **215** is disposed in the chamber **212** in order to depress the plate shaped check valve **185**. The resilient ripple regulating unit **200** effectively regulates the ripples even when the piezo element (cylinder shaped vibration pipe **114**) is activated by a drive signal of 122 Hz.

The buffer unit **300** is secured to the side wall of the outlet valve seat **180** by screws in a manner that the passage **184** formed in the outlet valve seat **180** communicates with a valve chamber **302** associated with an electromagnetic valve **301**. A rubber seal **310** ensures a tight connection between the buffer unit **300** and the outlet valve seat **180**. A buffer bag **304** is provided at the bottom of the buffer unit **300**. The buffer bag **304** is made of EPDM rubber of ASTM standard, "D1418". More specifically, the buffer bag **304** is secured to the body of the buffer unit **300** by means of a fastener **305** in a manner that the buffer bag **304** communicates with a passage **308** formed in the body of the buffer unit **300**. A liquid introducing opening **307** is formed at the upper end of the valve chamber **302** in order to introduce the liquid which should be filled in the hollow portion **124** and the cavity **127**. The liquid introducing opening **307** is closed by a screw cap **303**. When the plunger **306** is located at the uppermost position in the valve chamber **302**, the liquid introducing opening **307** is closed, and the valve chamber **302** is communicated with the buffer bag **304** through the passage **308**. When the plunger **306** is located at the lowest position in the valve chamber **302**, the passage **308** is closed, and the liquid introducing opening **307** is communicated with the valve chamber **302**.

That is, when the main power supply switch of the ink jet system printer is switched on, the electromagnetic valve **301** is activated to hold the plunger **306** at the lowest position.

Accordingly, when the ink jet system printer is placed in an operating condition, the passage **308** is closed by the plunger **306**. When the main power supply switch is switched off, the plunger **306** is shifted to the uppermost position by a spring (not shown) so as to open the passage **308**. When the liquid is desired to be introduced through the liquid introducing opening **307**, the plunger **306** is depressed downward against the spring to create a negative pressure within the valve chamber **302**, the circular shaped groove **181**, the cutaway portions **125**, the hollow portion **124** and the cavity **127**.

As already discussed above, when the main power supply switch of the ink jet system printer is switched on, the electromagnetic valve **301** is enabled to close the passage **308** through the use of the plunger **306**. Thus, the liquid is sealed in the valve chamber **302**, the hollow portion **124** and the cavity **127**. Under these conditions, when the drive signal of 122 Hz is applied to the cylinder shaped vibration pipe **114** made of the piezo element, the vibration of the cylinder shaped vibration pipe **114** is transferred to the cone portion **120B** of the cone shaped separator rubber **120** via the liquid filled in the cavity **127**, the cutaway portions **125** and the hollow portion **124**. The cone portion **120B** of the cone shaped separator rubber **120** repeats the stretching vibration in response to the vibration of the cylinder shaped vibration pipe **114**. In this way, the pressurized ink liquid is developed from the pressure chamber **121** to the chamber **212** via the plate shaped check valve **185**, and the ink liquid is introduced from the inlet passage **111** into the pressure chamber **121** via the plate shaped check valve **115**. The ripple included in the pressurized ink liquid is minimized in the chamber **212**, and the ink liquid is applied to the nozzle unit of the ink jet system printer through the outlet **214**.

When the ink jet system printer is placed in a non-operating condition, the plunger **306** is located at the uppermost position by means of the spring. The passage **308** is opened so that the valve chamber **302** is communicated with the buffer bag **304** through the passage **308**. Under these conditions, when the ink liquid siposed in the pressure chamber **121** freezes, the volume of the pressure chamber **121** increases. The expansion of the pressure chamber **121** pushes the liquid filled in the hollow portion **124** toward the valve chamber **302** via the cutaway portions **125**, the circular shaped groove **181**, and the passage **184**. Further, the liquid flows toward the buffer bag **304** which functions to absorb the expansion of the pressure chamber **121**.

The liquid filled in the cavity **127**, the hollow portion **124** and the valve chamber **302** is preferably the polyethylene glycol #200, and must satisfy the following conditions.

(1) The volume variation depending on the temperature must be minimum. This is because the liquid must accurately transfer the vibration of the cylinder shaped vibration pipe **114** to the cone shaped separator rubber **120** without regard to the temperature variation.

(2) The liquid must show the antifreezing characteristics. (The polyethylene glycol has the freezing point of about −70° C.) The water-color ink used in the ink jet system printer has the freezing point about −5° C. The liquid must function to abosorb the expansion when the water-color ink freezes.

(3) The liquid must show a low viscosity. The low viscosity ensures a stable transfer of the vibration of the cylinder shaped vibration pipe **114** to the cone shaped separation rubber **120**.

(4) The liquid must have a low saturation vapour pressure. (The polyethylene glycol has the saturation vapour pressure of about 10^{-2} Torr at 25° C.) The low saturation vapour pressure ensures the stable transfer of the vibration from the cylinder shaped vibration pipe **114** to the cone shaped separator rubber **120**.

The cone shaped separator rubber **120** should preferably have the same vibration transferring characteristics as the piezo element, and must have the resilience. The "D1418" of the ASTM standard shows the resilience of about 270 mm^3 when the thickness is about 0.3 mm, and the stiffness is 50°.

FIG. **4** shows an ink liquid supply system for an ink jet system printer of the charge amplitude controlling type, which includes the piezo activated pump system of FIGS. **2** and **3**.

A piezo activated pump system **41** of the construction shown in FIGS. **2** and **3** is connected to a nozzle unit **42** in order to supply the nozzle unit **42** with a pressurized water-color ink. The ink liquid emitted from the nozzle unit **42** is used to print desired symbols on a record receiving paper in a dot matrix fashion. The ink liquid not contributing to the actual printing operation is directed to a beam gutter **43**. The ink liquid collected by the beam gutter **43** is returned to an ink tank **46** via an electromagnetic cross valve **44** and a suction pump **45**. The ink tank **46** is connected to the piezo activated pump system **41** via an ink viscosity sensor unit **47**. When the viscosity of the ink liquid is higher than a preselected level, the ink viscosity sensor unit **47** develops a sonsor output to activate the electromagnetic cross valve **44** so that the dilution is supplied from a dilution tank **48** to the ink liquid supply system. At this moment, the beam gutter **43** is disconnected from the suction pump **45**.

The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications are intended to be included within the scope of the following claims.

What is claimed is:

1. An ink liquid supply system for an ink jet system printer comprising:

an ink liquid reservoir containing water-color ink;

a liquid supply pump system connected to introduce said water-color ink from said ink liquid reservoir, and developing a pressurized ink liquid;

first conduit means, disposed between said ink liquid reservoir and said liquid supply pump system, for supplying said water-color ink to said liquid supply pump system; and

second conduit means for supplying said pressurized ink liquid developed from said liquid supply pump system to a nozzle unit,

said liquid supply pump system comprising:

a cylinder shaped vibration pipe;

a cone shaped pressure chamber surrounded by a resilient member, said cone shaped pressure chamber being diposed in said cylinder shaped vibration pipe in a manner that a cavity is formed between said cylinder shape vibration pipe and said resilient member;

an inlet passage connected to said first conduit means;

an inlet valve disposed at said inlet passage;

an outlet passage connected to said second conduit means;

an outlet valve disposed at said outlet passage; and

a vibration transferring liquid filled in said cavity formed between said cylinder shaped vibration pipe and said resilient member.

2. The ink liquid supply system of claim **1**, wherein said vibration transferring liquid has a freezing point lower than that of said water-color ink.

3. The ink liquid supply system of claim **2**, said liquid supply pump system further comprising:

a buffer chamber communicated with said cavity so as to introduce said vibration transferring liquid from said cavity; and

valve means, disposed between said buffer chamber and said cavity, for selectively connecting said buffer chamber to said cavity.

4. The ink liquid supply system of claim **3**, wherein said valve means comprises an electromagnetic valve which is closed to disconnect said buffer chamber from said cavity when the liquid supply pump system is activated.

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